/////active interfaces

Project 02 - Design

BIPV scenarios for facade retrofitting: challenges in architectural design based on self-consumption approach

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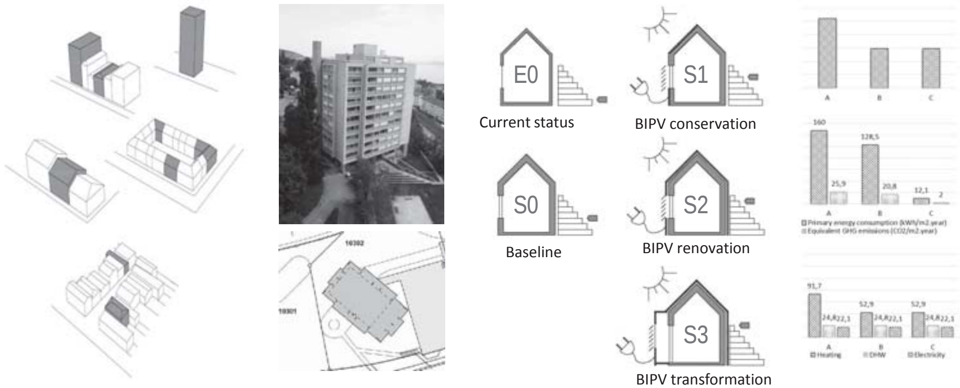
1st PhD Seminar | ACTIVE INTERFACES | Lausanne | 11.04.2016

Energy Turnaround
National Research Programme NRP 70

Phase 01 | Definition of Archetypes (Residential buildings)

A - Construction period	before 1919	1919-1945	1946-1970	1971-1985	1986-2005
B - Urban context	Isol / Adj. building	Isolated building	Isolated building	Isolated building	Isolated building
C – Roof potential	Sloped roof	Sloped roof	Sloped / Flat roof	Flat roof	Flat roof
D – Façade potential	1-4 floors	1-4 floors	1-4 floors	>7 floors	5-7 floors
E - Architectural quality Level of protection	Common II	Common II	Common II	Common II	Common / Unattractive II / III
	Arch. 1	Arch. 2	Arch. 3	Arch. 4	Arch. 5

Research | Main phases of the methodology



(1) IDENTIFICATION OF RESIDENTIAL ARCHETYPES > (2) SELECTION OF THE CASE STUDIES > (3) DESIGN SCENARIOS WITH BIPV SOLUTIONS > (4) MULTI-CRITERIA ASSESSMENT

Phase 02 | Case Study Selection | Archetype 4

First case study

A - Construction period	before 1919	1919-1945	1946-1970	1971-1985	1986-2005
B - Urban context	Isol / Adj. building	Isolated building	Isolated building	Isolated building	Isolated building
C – Roof potential	Sloped roof	Sloped roof	Sloped / Flat roof	Flat roof	Flat roof
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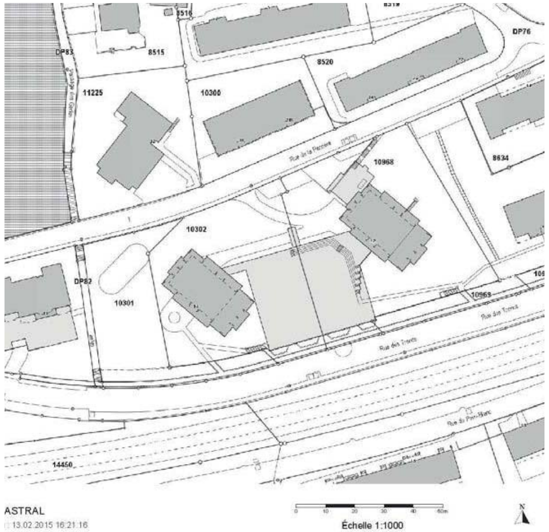
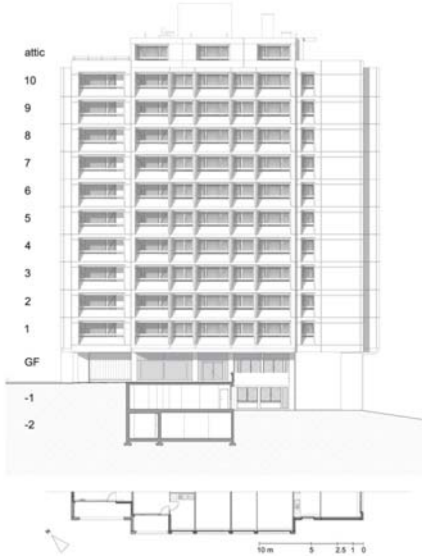
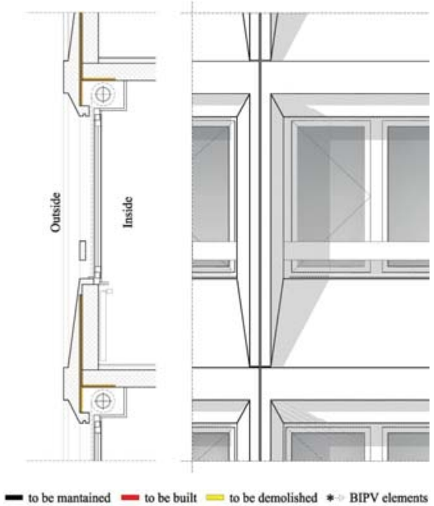
Phase 02 | Case Study Selection | Archetype 4



First case study : Rue Troncs 12 (Residental archetype 4, Period of construction: 1972-1973)

Phase 03 | Design scenarios | E0 – Current status





Phase 03 | Design scenarios with BIPV solutions

Current status

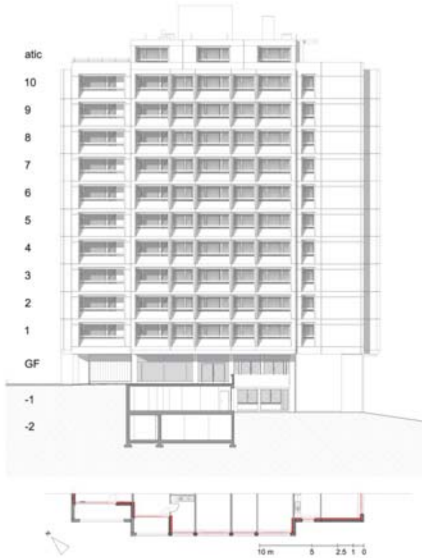
Baseline: Compliance with current legal requirements

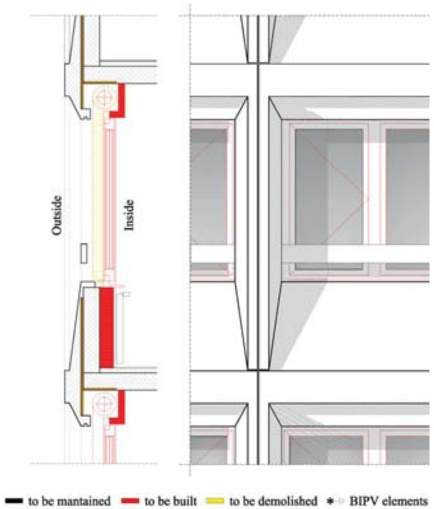
BIPV conservation: Maintaining the expression of the building while improving the energy performances of the building (at least current legal requirements)

BIPV renovation: Maintaining the general expressive lines of the building while reaching high energy performances (at least Minergie standard)

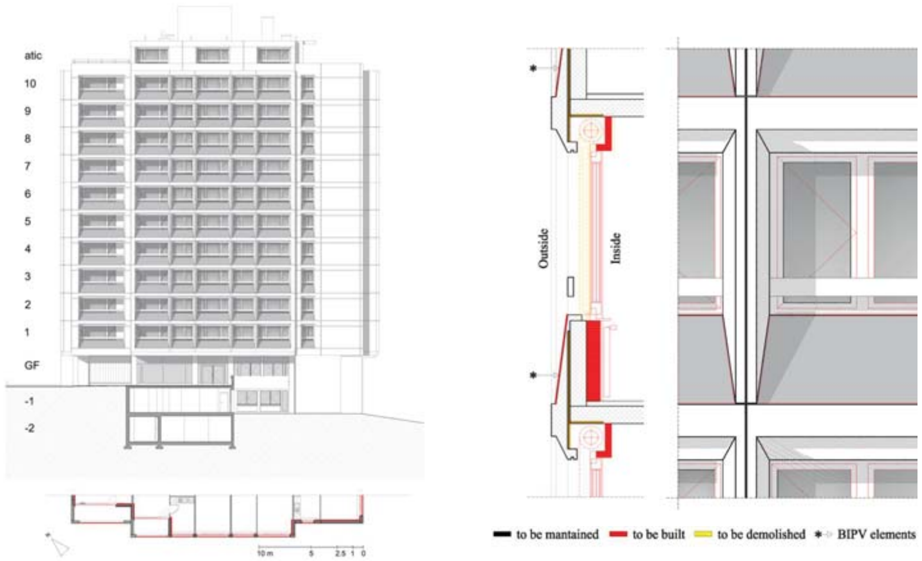
BIPV transformation: Best energy performances and maximum electricity production possible with aesthetic and formal coherence of the whole building (at least 2000 Watt Society | Energy strategy 2050)

Phase 03 | Design scenarios | S0 – Baseline

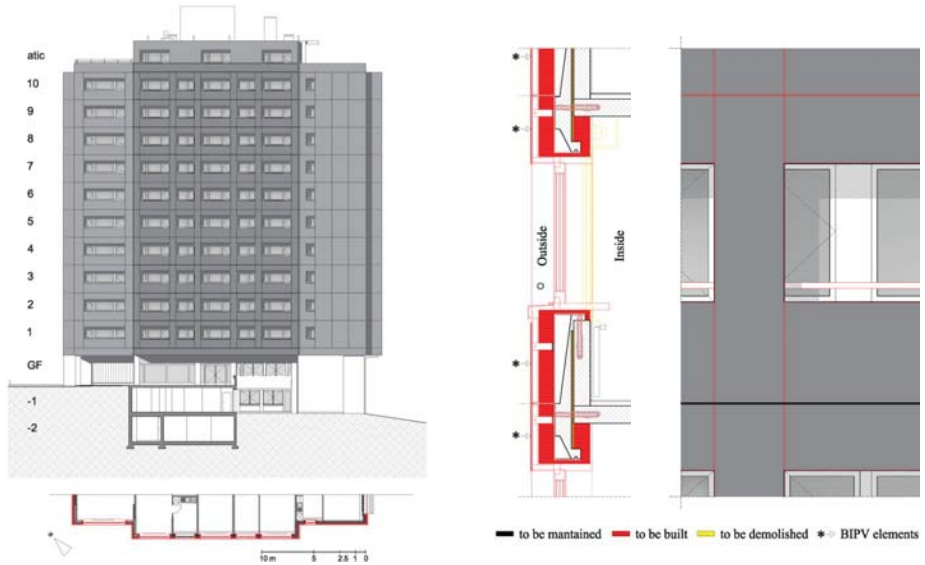




Phase 03 | Design scenarios | S1 – Conservation

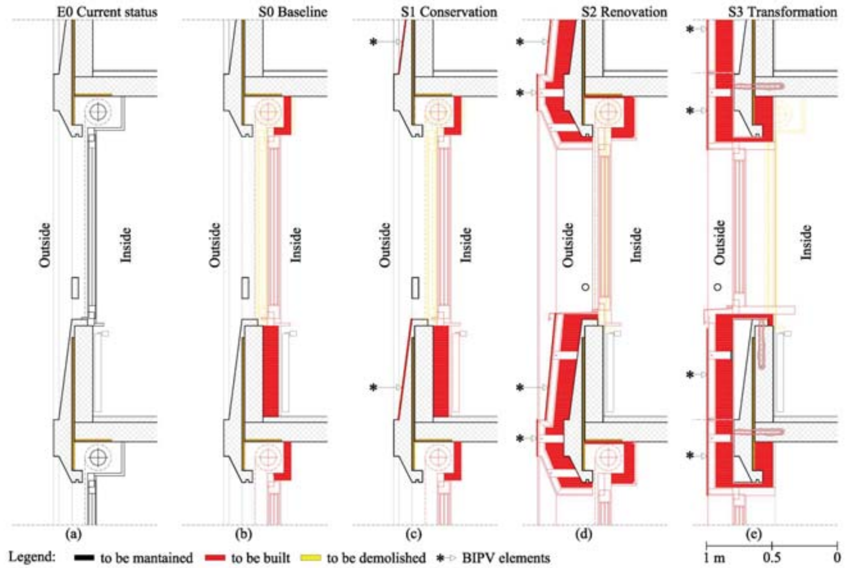


Phase 03 | Design scenarios | S3 – Transformation

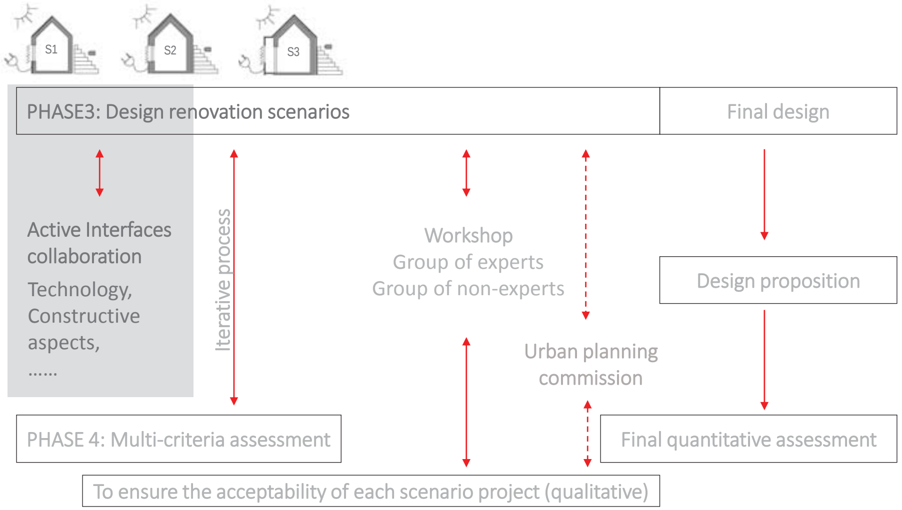


Phase 03 | Design scenarios | S2 – Renovation

Phase 03 | Design scenarios | Construction details

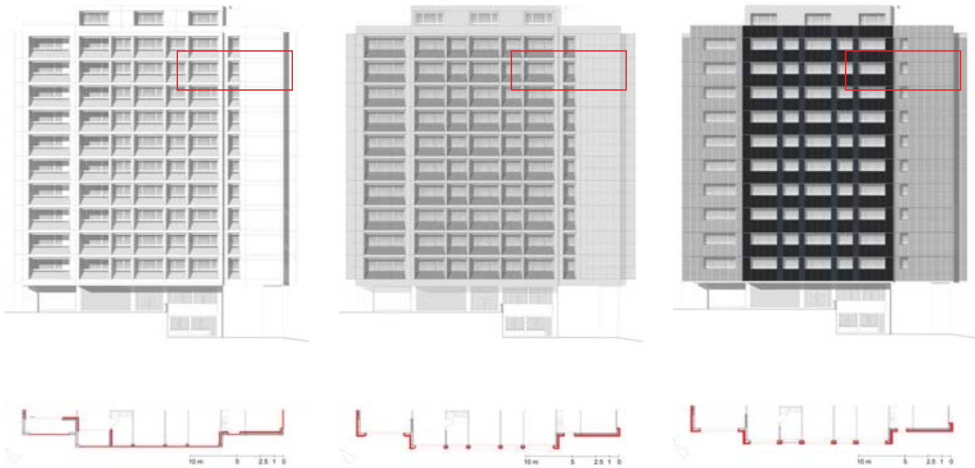


Phase 03 | Design and technological approach



Phase 03 | Design with techological approach

S1 - Conservation (DS – disruptive) *S2 - Renovation (TS – transformative)* *S3 - Transformation (ES - evolutive)*



Phase 03 | Design scenarios | Technological approach

(a)

Evolutive : Products directly issued from mainstream PV, but which naturally fits better for BIPV (e.g. “smart wire” modules, Metallization-Wrap-Through – MWT – modules).

(b)

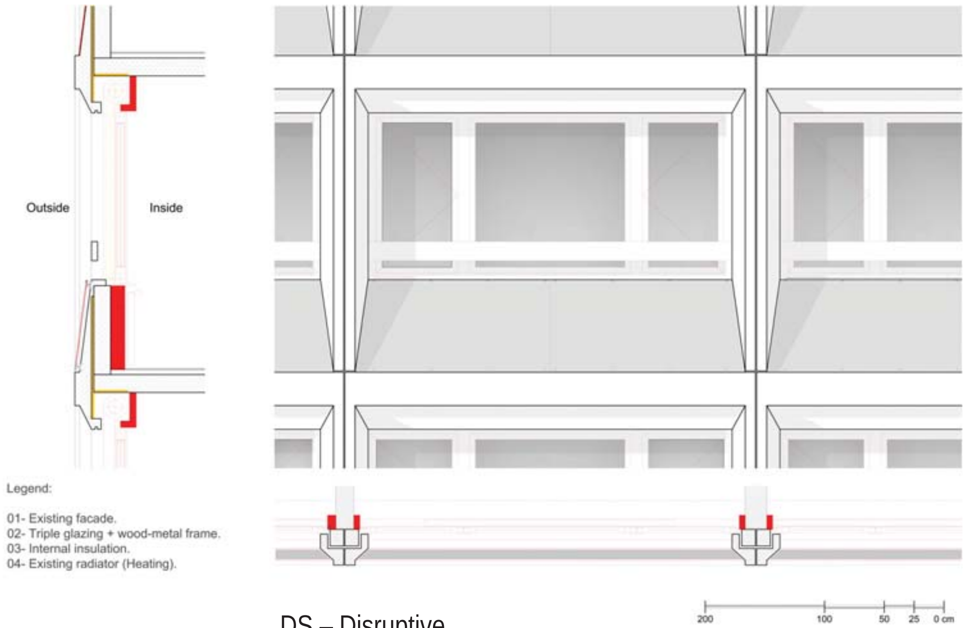
Transformative : Products based on low-cost “standard” technology products, but which integrate low-cost modifications, such as texture or colour variation with “adaptation” foils.

(c)

Disruptive : Products including customized-size products or on-site shaping of PV elements.

(a) Polycrystalline silicon PV module (55% of the market) with a black backsheet (SIGNATURE™ BLACK) - http://us.sunpower.com/
(b) White c-Si based PV modules (shiny & matt) as developed by CSEM and now commercialized by Solaxess.
(c) Customized-size PV modules by Meyer Burguer AG - www.meyerburger.ch

Phase 03 | Design with techological approach | S1 – Conservation



DS – Disruptive

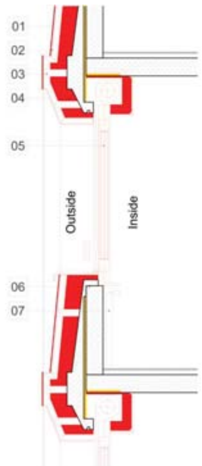
Phase 03 | Design with techological approach | S1 – Conservation

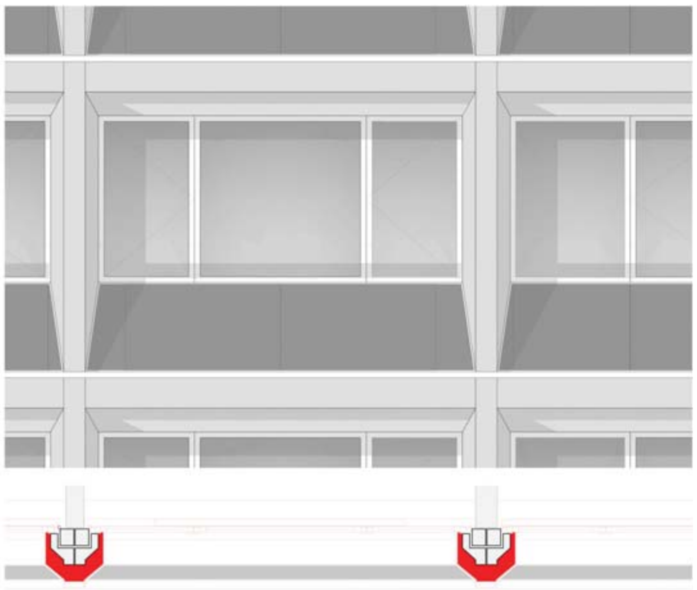
DS – Disruptive

Phase 03 | Design with techological approach | S2 – Renovation

TS – Transformative

Phase 03 | Design with techological approach | S2 – Renovation



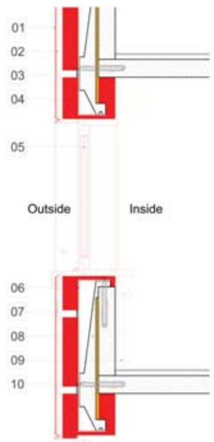


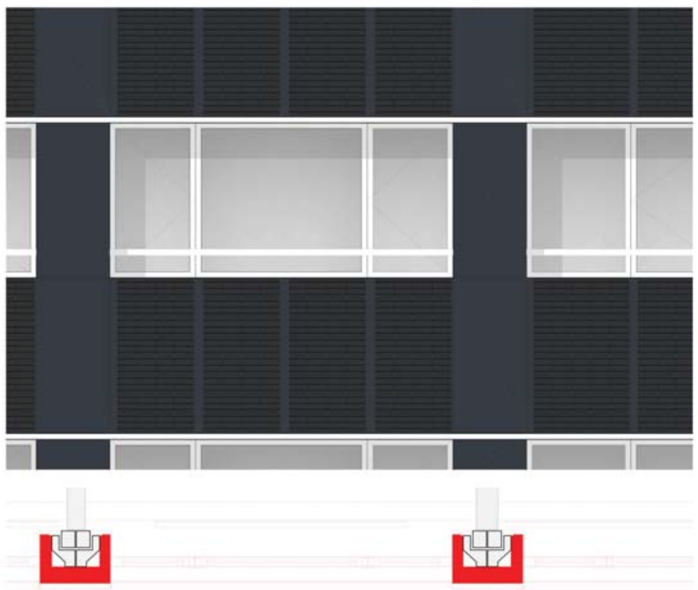
Legend:

01 - BIPV facade element.
02- Support of BIPV element.
03- Sub-structure of the ventilated facade.
04- Insulation.
05- Triple glazing + wood-metal frame.
06- Existing facade.
07- Existing radiator (Heating).

TS – Transformative

Phase 03 | Design with techological approach | S3 – Transformation

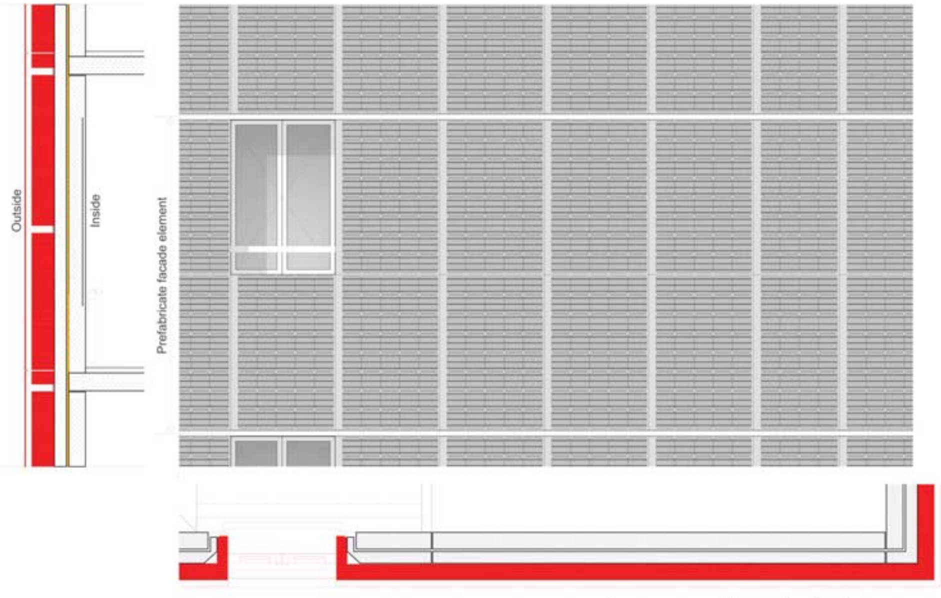




01 - BIPV facade element.
02- Support of BIPV element.
03- Sub-structure of the ventilated facade.
04- Insulation.
05- Triple glazing + wood-metal frame.
06- Metallic structure for regularization.
07- Fixation elements.
08- Existing facade.
09- Existing radiator (Heating).
10- Fixation regularization element

ES – Evolutive

Phase 03 | Design with techological approach | S3 – Transformation

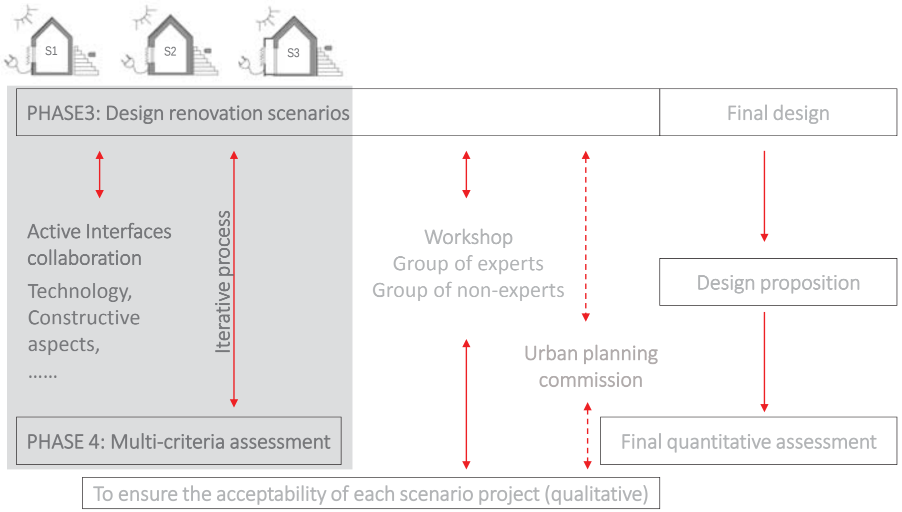


ES – Evolutive

Phase 04 | Multi-criteria assessment | Indicators

Assessment indicator	*Unit*	*Method / tool used*	*3D modelling LoD*
1. Energy and emissions			
- Primary energy consumption	kWh_{PE}/m^2.year	Energy Plus	LOD3
- Equivalent GHG emissions	CO_{2EQ}/m^2.year	Energy Plus	LOD3
2. LCA - Life Cycle Analysis			
- Embodied energy balance	MJ/m2.year	ecoinvent + KBOB	-
- Global warming potential	kgCO2/m2.year	ecoinvent + KBOB	-
3. Photovoltaic generation			
- PV Generation	kWh_{FE}/m^2.year	Energy Plus	LOD3
- Self-consumption	%	-	-
- Self-sufficiency	%	-	-
4. Indoor comfort			
- Daylight autonomy (DA) – 300 lux	% of time	Radiance / Daysim	LOD4
- Overheating	hours per year	Energy Plus	LOD3
5. Global cost-effectiveness			
- Annual rent increase	%	-	-
- Accumulated cost and Payback	CHF and years	-	-

Phase 04 | Multi-criteria assessment



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- Overheating	hours per year	Energy Plus	LOD3
5. Global cost-effectiveness			
- Annual rent increase	%	-	-
- Accumulated cost and Payback	CHF and years	-	-

Phase 04 | Multi-criteria assessment | Photovoltaic installation

What is the best indicator for the **BIPV** installation in renovation projects ?

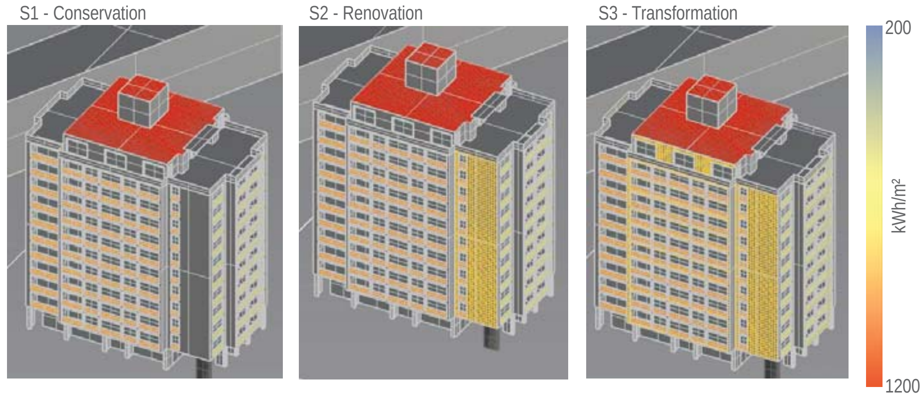
Annual electricity coverage ratio -> sending all the electricity to the grid

or

Self-consumption ratio

Phase 04 | Multi-criteria assessment | Photovoltaic installation

3- Photovoltaic installation | Irradiation simulation



Phase 04 | Multi-criteria assessment | Photovoltaic installation

Annual electricity coverage ratio: Ratio between the total production of PV electricity produced by the BIPV installation respect to the total electricity consumption.

(1) $$\textbf{Anual electricity coverage ratio}\ [\%] = \frac{\textbf{total anual PV generation}}{\textbf{total anual electricity needs}}$$

Self-consumption ratio: Percentage of electricity produced by the BIPV system that is consumed directly by the building. Shows the level of utilization on-site of the electricity produced by the BIPV system.

(2) $$\textbf{Self} - \textbf{consumption ratio}\ [\%] = \sum_{0}^{8760} \frac{\textbf{Hourly PV electricity consumption on} - \textbf{site}}{\textbf{Hourly PV production}}$$

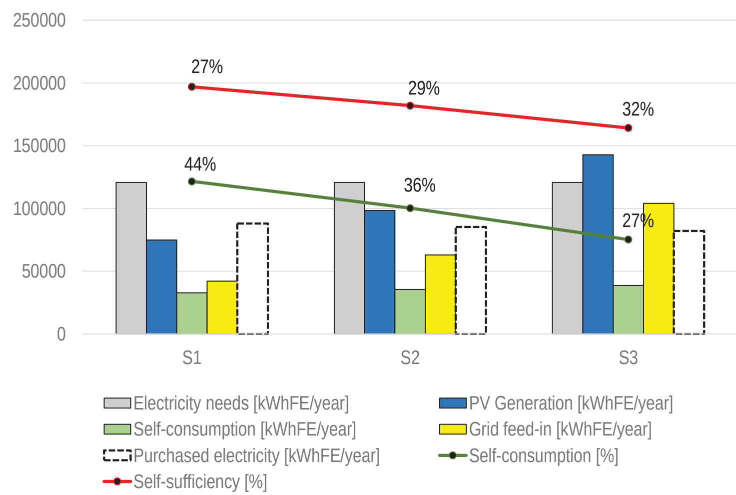
Self-sufficiency ratio: Ratio between the photovoltaic electricity consumed on-site by the total electricity needs. Shows the real coverage of the demand for electricity on the basis of self-consumption, equivalent to the level of energy independence of the building.

(3) $$\textbf{Self} - \textbf{sufficiency ratio}\ [\%] = \sum_{0}^{8760} \frac{\textbf{Hourly PV electricity consumption on} - \textbf{site}}{\textbf{Hourly electricity needs}}$$

Phase 04 | Multi-criteria assessment | Photovoltaic installation

3- Photovoltaic installation (annual analysis with hourly simulation)

Electricity needs: Equipment + Lighting



Phase 04 | Multi-criteria assessment | Photovoltaic installation

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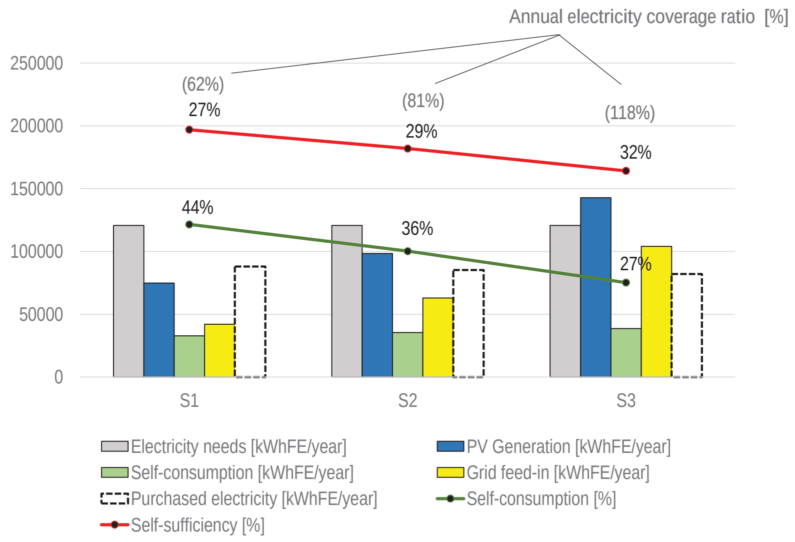
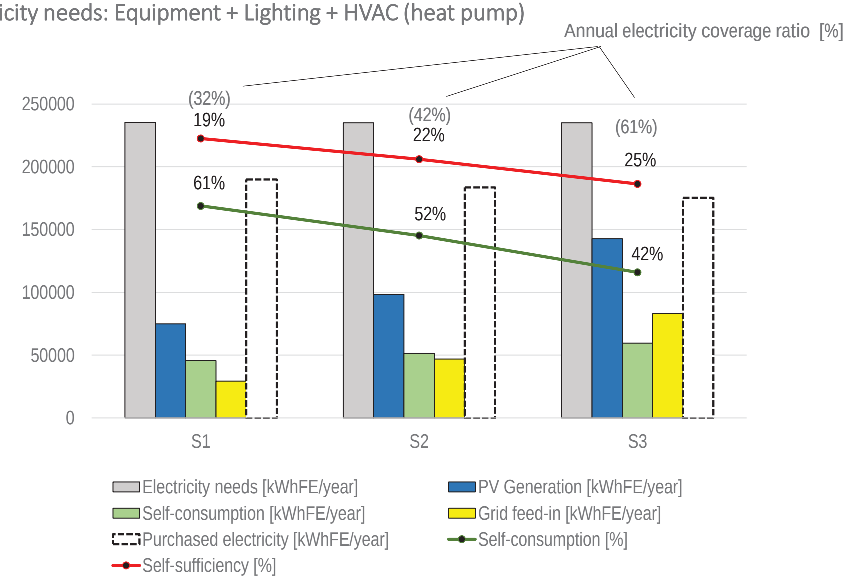
Electricity needs: Equipment + Lighting



Phase 04 | Multi-criteria assessment | Photovoltaic installation

3- Photovoltaic installation (annual analysis with hourly simulation)

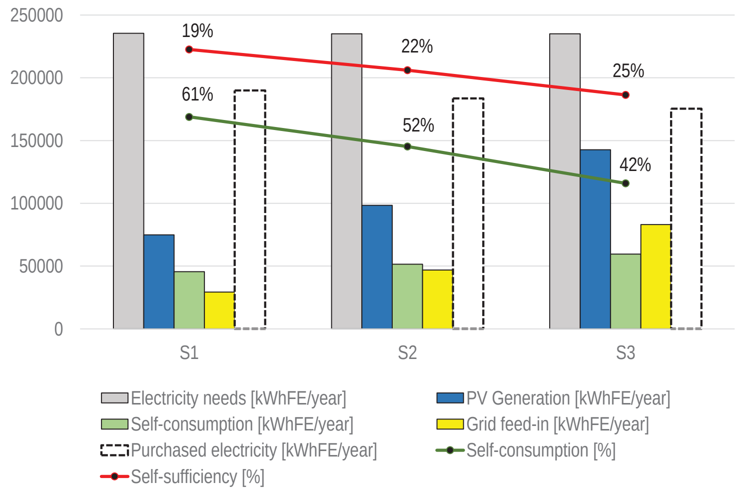
Electricity needs: Equipment + Lighting + HVAC (heat pump)



Phase 04 | Multi-criteria assessment | Photovoltaic installation

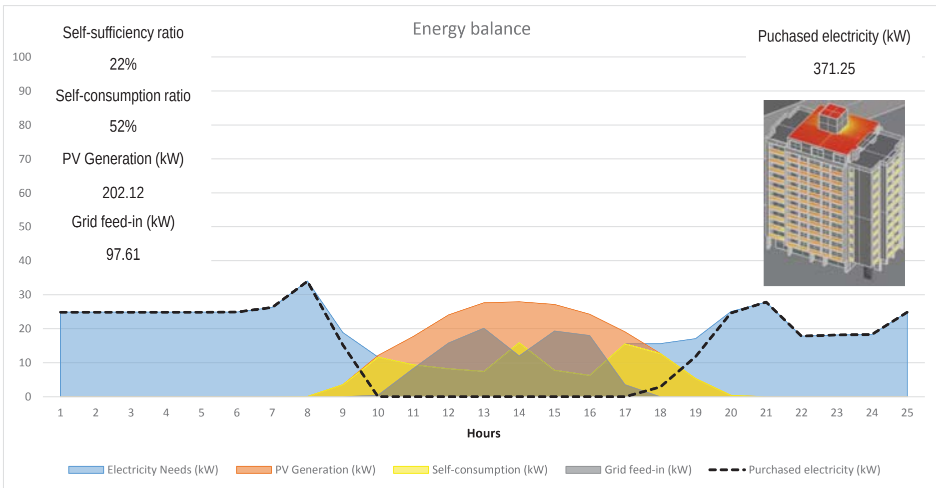
3- Photovoltaic installation (annual analysis with hourly simulation)

Electricity needs: Equipment + Lighting + HVAC (heat pump)



Phase 04 | Multi-criteria assessment | Photovoltaic installation

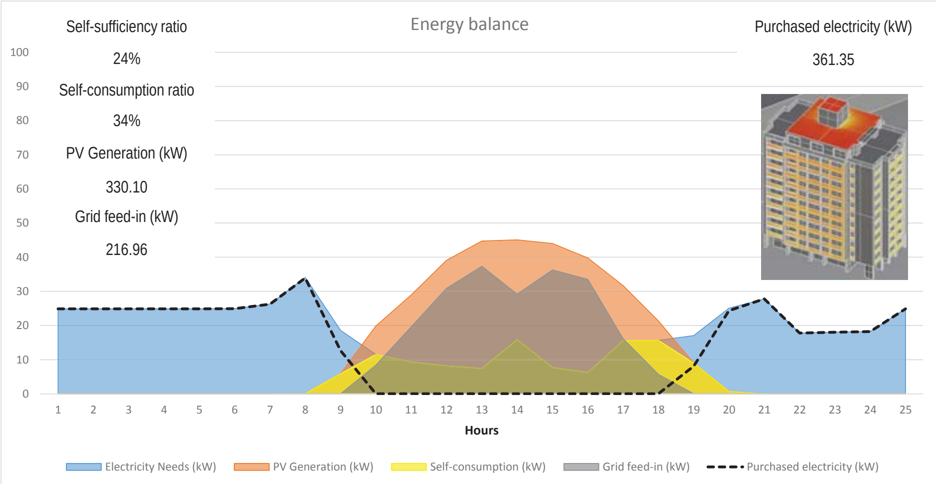
3- Photovoltaic installation (daily analysis)



Scenario S1 – Equipment + Light + HVAC (Electric heat pump) - Simulation day: 21 - 03

Phase 04 | Multi-criteria assessment | Photovoltaic installation

3- Photovoltaic installation (daily analysis)



Scenario S2 – Equipment + Light + HVAC (Electric heat pump) - Simulation day: 21 - 03

Phase 04 | Multi-criteria assessment | Photovoltaic installation

Study of the electricity production profile depending on the location of the active elements respect the electricity consumption profile.

- Case study – Design strategy based on scenario S3-Transformation

  A - BIPV system with active elements covering all South-West façade.

  B - BIPV system with active elements covering all South-East façade.

  C - BIPV system with active elements covering all North-East façade.

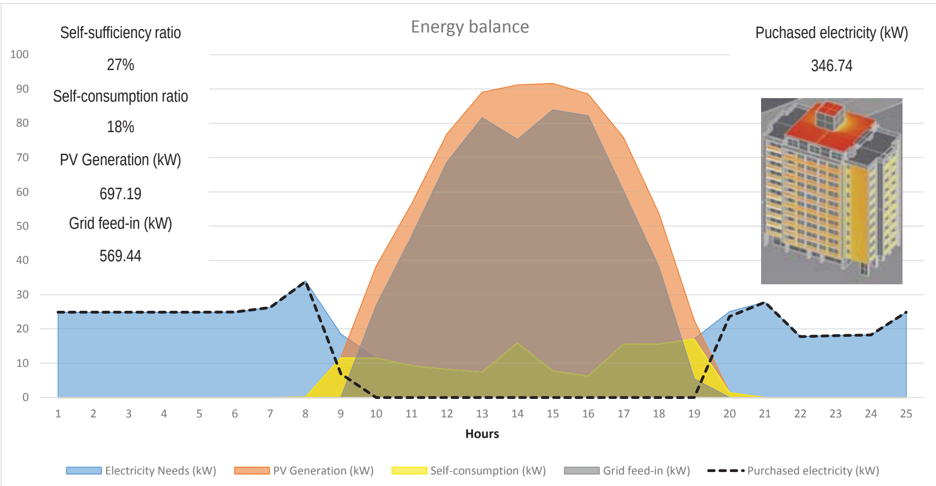
  D - BIPV system with active elements covering all North-West façade.

Objective:

Matching the electricity production with the electricity needs. It is essential to install BIPV elements in the specific location (façades) and in a good orientation and inclination (roof).

Phase 04 | Multi-criteria assessment | Photovoltaic installation

3- Photovoltaic installation (daily analysis)

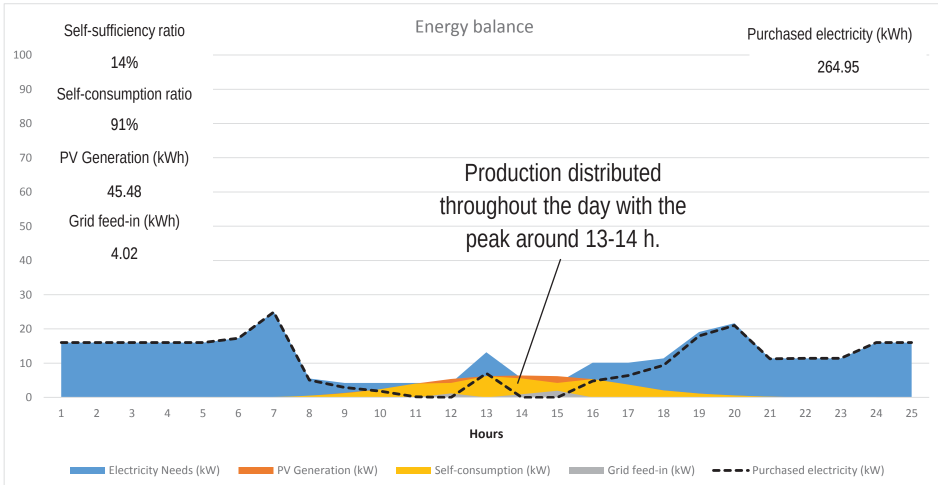


Scenario S3 – Equipment + Light + HVAC (Electric heat pump) - Simulation day: 21 - 03

Phase 04 | Multi-criteria assessment | Photovoltaic installation

3- Photovoltaic installation (daily analysis) – Simulation day: May, 21th

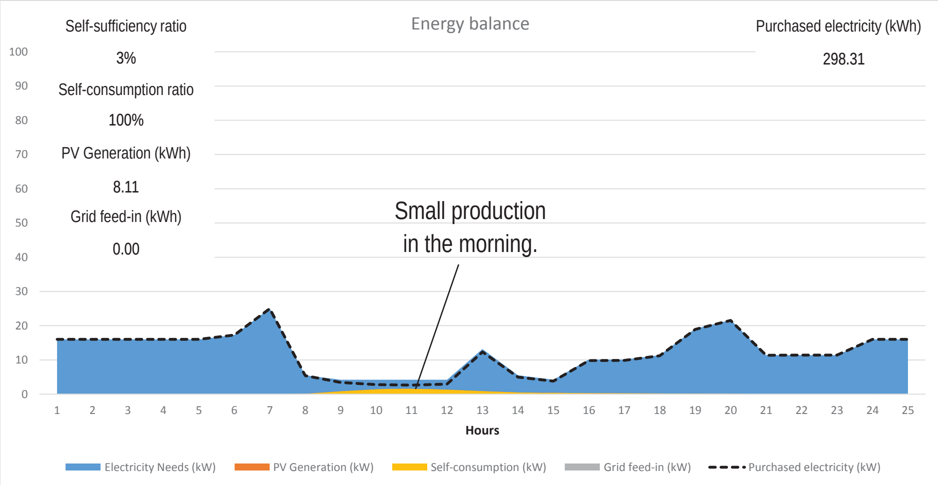
Façade: South-West



Phase 04 | Multi-criteria assessment | Photovoltaic installation

3- Photovoltaic installation (daily analysis) – Simulation day: May, 21th

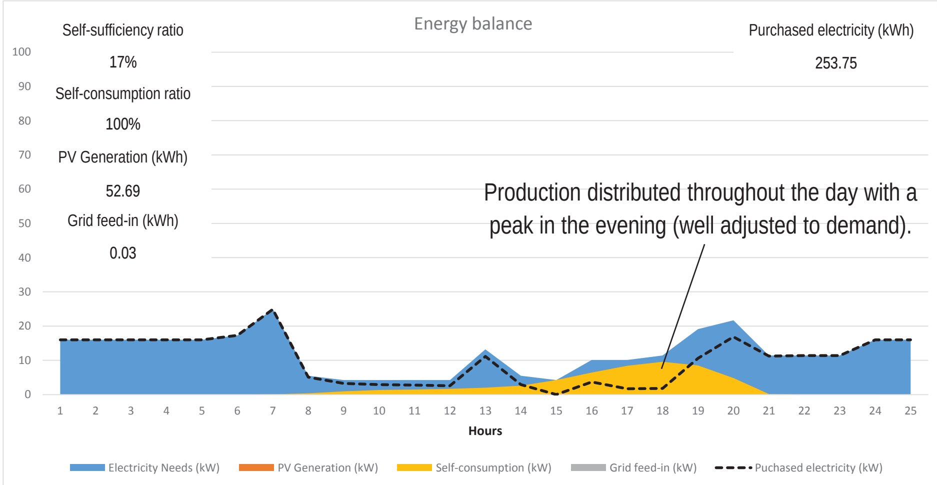
Façade: South-East



Phase 04 | Multi-criteria assessment | Photovoltaic installation

3- Photovoltaic installation (daily analysis) – Simulation day: May, 21th

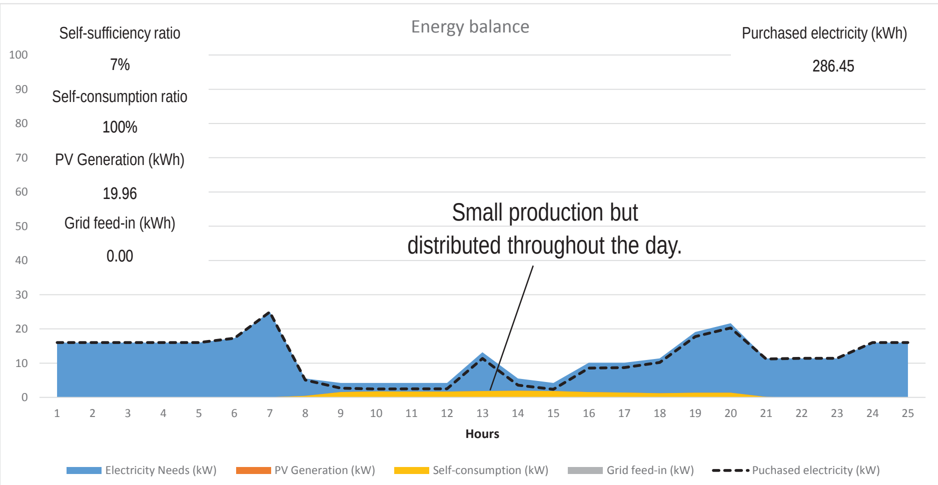
Façade: North-West



Phase 04 | Multi-criteria assessment | Photovoltaic installation

3- Photovoltaic installation (daily analysis) – Simulation day: May, 21th

Façade: North-East



BIPV | Renovation projects

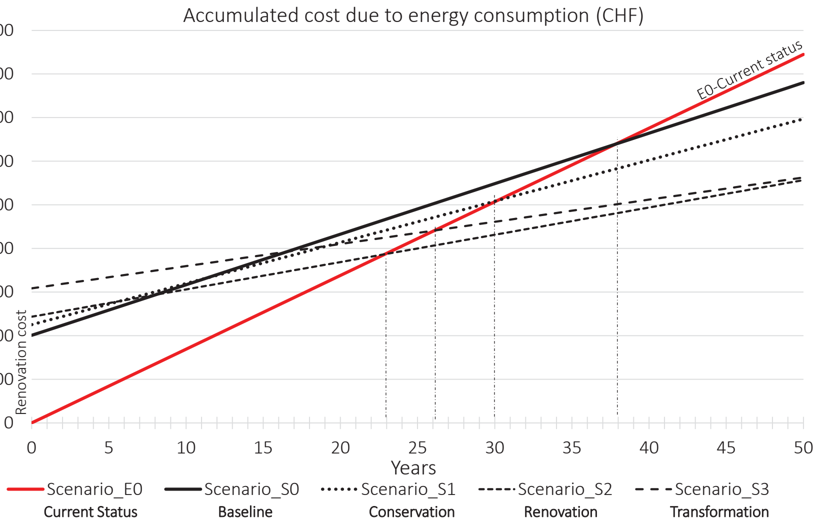
Open discussion:

Location of the active elements in the existing facades in order to maximize the self-consumption on-site (hourly simulation) and minimize the overproduction, avoiding the injection of the energy excess to the city grid.

Extra

Phase 04 | Multi-criteria assessment | Global cost-effectiveness

3. Global cost-effectiveness



Phase 04 | Multi-criteria assessment | Photovoltaic installation

3- Photovoltaic installation (annual analysis with hourly simulation)

Electricity needs: Equipment + Lighting

Scenario	*S1*	*S2*	*S3*
- Electricity needs [kWh_{FE}/year]	120704	120704	120704
- **PV Generation [kWh_{FE}/year]**	**74879**	**98382**	**142727**
- Self-consumption [kWhFE/year]	32759	35502	38653
- **Self-consumption [%]**	**44%**	**36%**	**27%**
- Grid feed-in [kWh_{FE}/year]	42120	62880	104074
- Purchased electricity [kWh_{FE}/year]	87945	85202	82051
- **Self-sufficiency [%]**	**27%**	**29%**	**32%**
- **Annual electricity coverage ratio [%]**	**62%**	**81%**	**118%**

Electricity needs: Equipment + Lighting + HVAC (heat pump)

Scenario	*S1*	*S2*	*S3*
- Electricity needs [kWh_{FE}/year]	235416	235033	235033
- **PV Generation [kWh_{FE}/year]**	**74879**	**98382**	**142727**
- Self-consumption [kWhFE/year]	45531	51456	59589
- **Self-consumption [%]**	**61%**	**52%**	**42%**
- Grid feed-in [kWh_{FE}/year]	29349	46926	83137
- Purchased electricity [kWh_{FE}/year]	189885	183577	175444
- **Self-sufficiency [%]**	**19%**	**22%**	**25%**
- **Annual electricity coverage ratio [%]**	**32%**	**42%**	**61%**